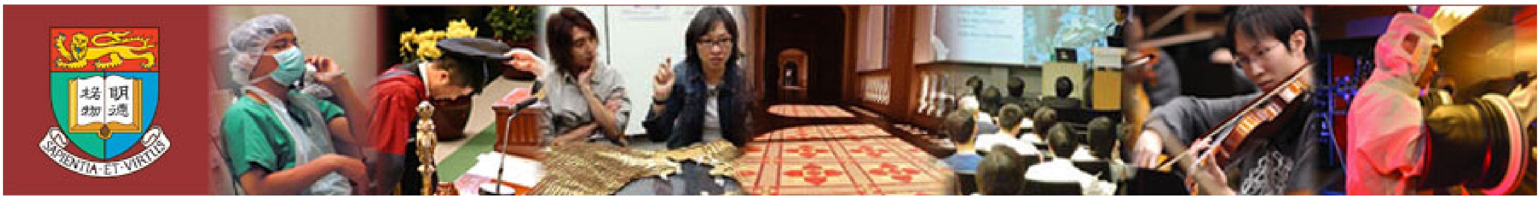


Title	**The recognition of isolated and interleaved melodies by children**
Other Contributor(s)	**University of Hong Kong**
Author(s)	**Chau, Ching, Christy**
Citation	
Issued Date	**2005**
URL	**http://hdl.handle.net/10722/56199**
Rights	**Creative Commons: Attribution 3.0 Hong Kong License**

The recognition of isolated and interleaved melodies by children

CHAU Ching, Christy

A dissertation submitted in partial fulfillment of the requirements for the Bachelor of Science (Speech and Hearing Sciences), The University of Hong Kong, April 30, 2005.

Abstract

Children aged 3 to 10 listened first to a familiar and an unfamiliar standard melody, and then to an isolated (experiment 1) or an interleaved comparison melody (experiment 2). Children judged whether the standard and comparison melodies were the same or different. The isolated comparison melodies included the standard melody, contour-preserved and contour-violated transformations. The interleaved comparison melodies were the isolated comparison melodies interleaved with distracter tone sequences with the mean frequency separation of 0, 6 and 12 semitones. For isolated comparison melodies, participants performed better with familiar than unfamiliar melodies, and with same than different melody pairs. Older children performed better than younger ones. For interleaved comparison melodies, there was no difference in performance on the basis of melody familiarity and age. Participants performed better with different than same melody pairs, and with the frequency separations of 0 and 6 than 12 semitones.

The recognition of isolated and interleaved melodies by children

Musical sequences and speech are both complex, since they consist of many rapidly changing elements distributed over time, such as pitch patterns and rhythm. The listener must organize these rapidly changing elements into larger units or patterns and extract meaning from them. (Morrongiello, Trehub, Thorpe, & Capodilupo, 1985). But as the musical piece or the speech progresses, there is no time to process those elements consciously in detail. Instead, the processing of those elements is automatic and unconscious. (Dowling, 1999) This study investigated how children process musical sequences, or melodies, and the different factors that affect their processing.

A melody is a sequence of pitches organized in a particular pattern. (Dowling, 1994) A melody is perceived and memorized based on intervals, tonality, contour and rhythm. Intervals are the distance between two notes. Tonality is the degree of conformity of the intervals of the successive notes of a melody to the interval patterns of the musical scale of a particular kind of music, usually the Western music. Contour of a melody is the outline of the rising and lowering of the pitches in a melody. (Morrongiello et al., 1985). In this study, we will focus on the role the contour plays in perceiving melodies. Before adults are able to process the above elements automatically, a lot of perceptual learning is needed through their experience with music in infancy and childhood. (Dowling, 1999) So studies of perception of melodies have been done on infants and children, to investigate the rudimentary abilities of infants and children in processing melodies.

In the study by Chang and Trehub (1977), five-month-old infants were adapted to hear a 6-note melody. When the melody was shifted three semitones in pitch and its contour was changed, a deceleration of the heart rate of the infants was detected, indicating that they heard something new. This finding shows that infants can distinguish melodies by the contour.

Cohen, Thorpe and Trehub (1987) (experiment 1) used five-note standard melodies consisting of the component notes of a major triad and minor triads in investigating infants' perception of melodies. The contrast melodies were the transposition of the standard melodies to prevent the discrimination of the melodies using absolute frequencies of the notes. For the 'change' trials, the second and fourth notes of the contrast melodies were increased or decreased one semitone. maintaining the contour. The infants were able to turn their heads to indicate that they heard the semitone change in the change trials. So it reflected that even when contour was maintained, infants differentiated between melodies differing in frequency ratios.

A study by Trehub, Bull and Thorpe (1984) had different findings from that of Cohen, et al. (1987). In the study by Trehub, et al. (1984) (experiment 1), six-note melodies were used as the standard. In the change trials, the contrast melodies included i) transposition, ii) contour-preserving transformation with intervals changed but the first and last notes and the contour remained the same as the standard, iii) octave-change/contour-preserving transformation in which some notes were displaced up or down one or more octaves but the contour was preserved, and iv) octave-change/contour-violating transformation in which some notes were displaced up or down one or more octaves but the contour was changed. The infants' performance indicated that they confused the transposition and contour-preserved transformation with the standard. So this study indicated that infants failed to discriminate melodies using frequency ratios.

In investigating the melody perception of children, both familiar and unfamiliar melodies have been used. In the study by Pick, et al. (1988) (experiment 4), children aged four to six years listened to familiar and unfamiliar standard melodies and their comparison melodies: contour- and rhythm-preserved rule-generated transformation for familiar melodies, contour- and rhythm-preserved rule-generated and composer generated transformation for unfamiliar melodies, and other melodies. The children were able to judge most contour- and rhythm-preserved transformation of both familiar and unfamiliar melodies as different from the standard. The findings indicated that children were able to use frequency ratios to recognize melodies. In another experiment (experiment 5) Pick, et al. (1988) asked children aged 5 to 5.8 years to rate the degree of similarity between a familiar standard melody and other unfamiliar melodies, rhythm-preserved transformation and rhythm- and contour-preserved transformation. The children rated the rhythm- and contour-preserved transformation as the most similar to the standard, then the rhythm-preserved transformation, and lastly the other unfamiliar melodies. So it indicated that besides recognizing the difference in frequency ratio of a familiar and unfamiliar standard and its contour- and rhythm-preserved transformation to judge them as different, the children were also able to recognize the similarity between a familiar standard and its contour- and rhythm-preserved transformation due to the same contour.

The study by Morrongiello, Trehub, Thorpe and Capodilupo (1985) (experiment 1) investigated the perception of unfamiliar melodies by children aged 4.1 to 5.5 years. All the transformed melodies had the same first and last note as the standard melody. Two transformed melodies were formed by reordering the component notes of the standard so that all five intervals were changed in one transformed melody while only two intervals were changed in the other, but the contour was changed in both melodies. Two other transformed melodies were formed by substituting new tones for the four internal tones of the standard and maintaining the contour of the standard in one transformed melody while changing the contour in the other. For the transformed melodies with reordered notes, the children performed better in the melody with five intervals changed than with two intervals changed. For the transformed melodies with new notes, they performed better in the contour-violated melody than in the contour-preserved melody. There was no difference in performance between the contour-violated melody with reordered notes and the contour-violated melody with new notes. So it indicated that the children were able to discriminate unfamiliar melodies using the difference in contour and frequency ratios. But the children were better in recognizing the contour-violated melody with new notes as different than the contour-preserved melody with new notes. This finding indicated that contour was a more important cue than frequency ratio in recognizing unfamiliar melodies. The children also performed better in the melody with reordered notes with five intervals changed than with two intervals changed. So the melody with a greater degree of contour change, that is, more intervals changed, was easier to be discriminated.

Trehub, Morrongiello and Thorpe (1985) compared the perception of familiar melodies of children aged four to six years and adults. Adults had better performance than children. But both groups rejected more contour-violated transformation as the same as the standard familiar melody than contour-preserved transformation. They also accepted the transposition as the same as the standard. So this finding indicated that the children used both frequency ratio and contour in discriminating familiar melodies. Children's more rejection with contour-violated transformation as the same as the standard further indicated that contour was a more important cue than frequency ratio in familiar melody perception.

According to the previous studies, children used both contour and frequency ratios in recognizing both familiar and unfamiliar melodies. But no comparison was made between familiar and unfamiliar melodies to determine any difference in performance. Also, the children participants in the previous studies came from a small age range. Their performance was analyzed as a whole. This study investigated the effect of contour on the perception of both familiar and unfamiliar melodies by children aged three, four, five, six and ten to document the developmental change in melody perception.

In reality, we seldom perceive a speech signal or a melody in isolation. We often listened to speech with background noise and also hear a melody with accompaniment played by different instruments or sung by different people. But we can decompose the complex signal in a pre-attentive way into independent perceptual entities, called auditory streams, to attend to speech in a noisy environment and focus on one voice part in a polyphonic music. (Bey & McAdams, 2003) Therefore, a second goal of the study is to investigate the children's perception of familiar and unfamiliar melodies interleaved with distracter tone sequences, by playing the tones of the melody and the distracter sequence alternately.

Infants already showed the perceptual grouping of sounds by pitch. In a study by Trehub and Thorpe (1989), a six-note melody, in which the first three notes were repetition of a tone and the last three were repetition of another tone, was played repeatedly to infants. They detected a change in the melody when a temporal gap was introduced within the first three notes or the last three notes. But they did not detect the change when the temporal gap was introduced between the first three notes and the last three notes. This finding indicated that the infants regarded the first three notes as a perceptual group and the last three notes as another perceptual group, by using their pitch.

A study to investigate the perception of interleaved melodies was performed on adults by Dowling (1973). The standard was a five-note unfamiliar melody. The comparison melody was an exact imitation of the standard or a new unfamiliar melody with a different contour. The comparison melody was interleaved with a background melody. The background melody started on the same note as the comparison melody. So the pitch ranges of the comparison and background overlapped. The background melody also started on the note six or 12 semitones above the starting note of the comparison so that the pitch ranges did not overlap. The participants discriminated the melodies better when the pitch ranges of the comparison and background melodies did not overlap. So the study indicated that the degree of overlap affected the participants' recognition of interleaved melodies.

In the study of the perception of interleaved melodies on adults by Bey and McAdams (2003), the order of presentation of the standard and interleaved comparison melodies was different from that of Dowling's (1973) study. In Dowling's (1973) study, the standard melody was played before the interleaved comparison melody. But in the study by Bey and McAdams, the melodies were played in reversed order, to minimize the knowledge provided to the participants about the standard melody before the comparison melody was played. As a result, the primitive organization of auditory streams can be involved maximally. (Bey & McAdams, 2003). Also, in the study by Bey and McAdams (2003), besides the mean frequency separation of zero, six, 12 semitones as used in the study by Dowling (1973), the frequency separation of 24 semitones was also used. Participants' performance in discriminating the interleaved comparison melodies improved as the frequency separation increased. So the findings in this study agreed with that of Dowling (1973) that the frequency separation between the comparison and background melodies, or the overlap of the pitch ranges, affected the participants' recognition of interleaved melodies. From the results, Bey and McAdams also estimated that the interleaved melodies were recognized in more than 50% of the time when the frequency separation between the background and comparison melodies was more than about 10 semitones.

In this study, children aged three to six and ten will be asked to recognize the interleaved melodies with the frequency separation of zero, six and 12 semitones to see if the findings in the studies by Dowling (1973) and Bey and McAdams (2003) can be replicated. Also, we will compare the performance among children aged three, four, five, six and ten, and the performance of familiar and unfamiliar melodies, to look for any possible differences in performance. Moreover, we will investigate whether the contour plays a different role in the recognition of isolated and interleaved melodies.

This study aims: 1) to compare the role of contour in children's perception of familiar and unfamiliar isolated and interleaved melodies, 2) to determine any developmental change in perception of isolated and interleaved melodies, 3) to compare children's performance in perception of interleaved melodies with distracter tone sequences of different mean frequency separation.

Experiment 1: Recognition of Isolated Melodies

The aim of experiment one was to determine the effect of contour on children's perception of familiar and unfamiliar melodies. Also, the performance of the participants from different ages will be compared to see if there is any difference. It was expected that the findings in this study will replicate that of Trehub, Morrongiello and Thorpe (1985) and Morrongiello, Trehub, Thorpe and Capodilupo (1985). So for the different melody pairs, the participants would perform better with contour-violated transformation than contour-preserved transformation.

Method

Participants

Seventy-one children from three kindergartens and two primary schools participated in this experiment. Twenty children were excluded from the sample because they either did not understand the task of hearing screening (n = 4), failed in the hearing screening (n = 14), and failed in the training phase of the experiment (n = 2). Three children were absent on the day of performing the experiment. The final sample of 48 children consisted of 25 males and 23 females, with the age range of 3;03 – 6;10 and 10;00 – 10;11, and a mean age 6.35.

Stimuli

For the training phase, the standard melody used was the first musical phrase of "Mary had a little lamb", consisting of seven notes. The comparison melody used in the different pairs was the contour-preserved transformation of "Mary had a little lamb", made by lowering the third note of "Mary had a little lamb" down 4 semitones (ST).

For the testing phase, the familiar standard melodies used were the first musical phrases of "Mary had a little lamb" and "Old McDonald had a farm", each consisting of seven notes. The unfamiliar standard melodies used were the rearrangement of the notes of the familiar standard melodies in a random order. The contour preserved transformations of the familiar standard melodies were made by lowering the third note of "Mary had a little lamb" and the fourth note of "Old McDonald had a farm" down four ST. The contour violated transformations of the familiar standard melodies were made by raising the third note of "Mary had a little lamb" and the fourth note of "Old McDonald had a farm" up four ST. The contour preserved transformations of the unfamiliar standard melodies were made by lowering the second notes of rearranged "Mary had a little lamb" and rearranged "Old McDonald had a farm" down four semitones (ST). The contour violated transformations of the unfamiliar standard melodies were made by raising the second notes of rearranged "Mary had a little lamb" and rearranged "Old McDonald had a farm" up four semitones (ST). Appendix 1 listed the frequencies of the component notes of the familiar and unfamiliar melodies and their transformations.

The tones of the melodies were complex tones. Each tone was 120ms in duration. The intertone intervals were 180ms in duration. Each melody was 1.92s in duration. Each tone of the melodies was presented at an average intensity level of 74dBA, measured with fast reading setting.

Apparatus

In the hearing screening administered on the participants, a GSI-17 audiometer was used. The Custom Software written with Runtime Revolution Development Software was used to incorporate the melodies and the pictures, which acted as feedback to the participants' responses. Then the software was run in the IBM ThinkPad 570E notebook computer (Model 2644-5AH), with a Crystal Sound Fusion sound card, to perform the experiment on the participants. During the training and testing phase, the Sennheiser HD545 reference headphone was connected to notebook computer. The participants wore the headphone to hear the melodies.

Procedure

The participants participated in the experimental procedure individually. They were tested in rooms with the average background noise level of 44dBA. A hearing screening was first administered on the participants. They were tested with pure tones of 500Hz, 1000Hz, 2000Hz and 4000Hz at 25dBHL. The participants were judged as passing the hearing screening if they were able to hear at least three of the pure tones at 25dBHL.

Each participant sat beside the experimenter, facing the notebook computer so that he/she was able to see the pictures shown on the screen. During the experiment, the participant was asked to listen to two songs sung by two animals. The first song was sung by an animal as shown in a picture on the computer screen. The second song was sung by an animal hidden in a house shown in another picture. He/She had to tell whether the two songs were the same or different. If they were the same, this meant that the two songs were sung by the same animal. The experimenter clicked the “yes” button on the screen for the participant. If they were different, it meant that the two songs were sung by different animals. The experimenter clicked the “no” button on the screen for the participant. After that, a picture of an animal, which was the same as that shown when the first song was played, would be shown if the participant’s response was correct. But a picture of a red cross would be shown if the participants’ response was incorrect. Then the next trial would be presented after the participant was ready and the clinician clicked the button “go next trial”.

The experimental procedure consisted of two phases: training phase and testing phase. In the training phase, the participants had to produce five consecutive correct responses within a maximum of 20 trials. The same number of same and different melody pairs were presented. The order of presentation was randomized so that it was different for every participant. If the participant was not able to get five consecutive correct responses within the 20 trials, he/she would fail in the training and would not proceed to the testing phase.

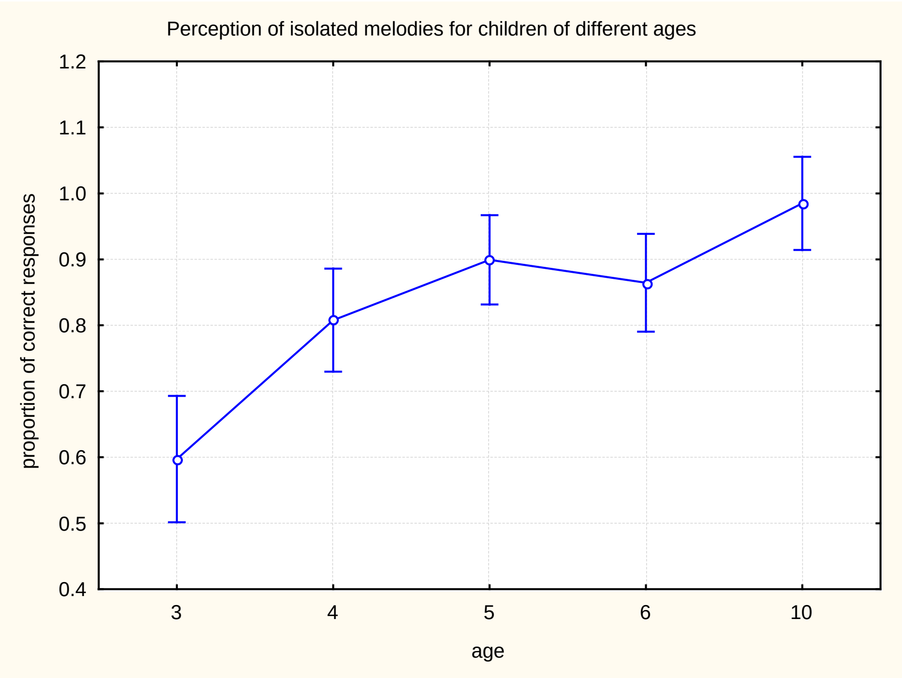
In the testing phase, the same number of same and different melody pairs were presented. The order of presentation was also randomized. For the different melody pairs, there were equal number of pairs with contour-preserved transformation and contour-violated transformation. Participants were tested with all the two familiar and two unfamiliar melodies. There were two trials for each condition using each of the four melodies. As a result, in the testing phase, there were 32 trials. The participants had to finish all the trials. The hearing screening and the experiment lasted about 20 minutes.

Results

The data consisted of the proportion of correct responses for same and different melody pairs. A mixed analysis of variance with age (age three, four, five, six and ten) as a between-subjects factor and melody familiarity (familiar and unfamiliar melodies), types of comparison melodies (standard melody, contour-preserved transformation, contour-violated transformation and melody (Mary had a little lamb, Old McDonald had a farm) as within-subjects factors was performed on the proportion scores of correct responses. The participants performed significantly better with familiar melodies than unfamiliar melodies, $F (1, 43) = 18.82$, $p < 0.05$. There was also a significant main effect of types of comparison melodies, $F (2, 42) = 7.07$, $p < 0.05$. Participants have more correct responses in discriminating same melody pairs than different melody pairs with contour-preserved transformation. There were also more correct responses in discrimination of different melody pairs with contour-preserved transformation than with contour-violated transformation. But post-hoc comparison using Tukey HSD test did not show any significant difference between any two types of comparison melodies.

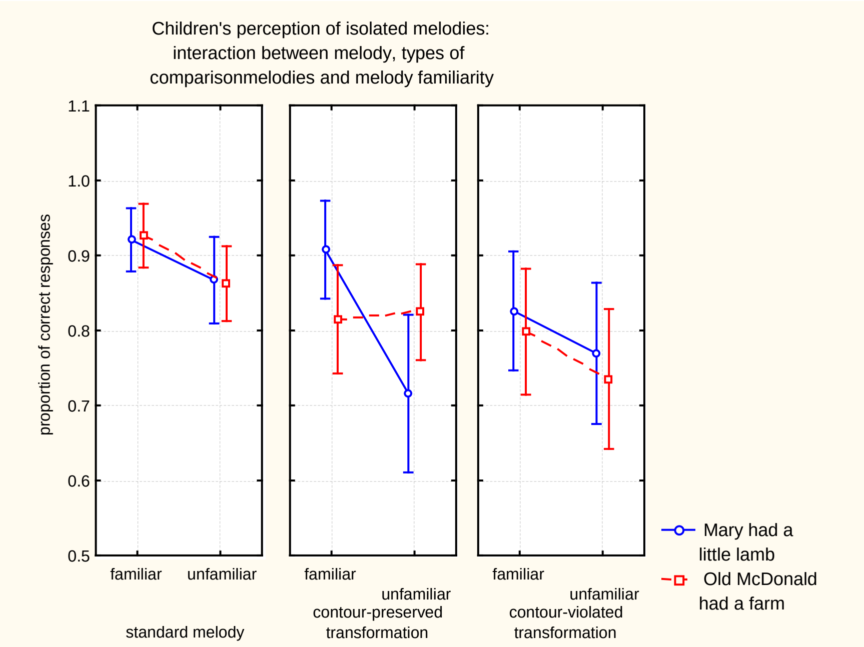
There was also a significant main effect of age, $F(4, 43) = 11.62$, $p < 0.05$. In particular, post-hoc comparison using Tukey HSD test showed that participants of age four, age five, age six and age ten performed significantly better than participants of age three. Participants of age ten also performed significantly better than age four. The performance of the participants of different ages is shown in Figure 1.

Figure 1: Performance in perception of isolated melodies by participants of different ages



In addition, there was a significant melody × types of comparison melodies × age interaction, $F(8, 86) = 2.11$, $p < 0.05$, and a significant melody familiarity × melody × types of comparison melodies interaction, $F(2, 86) = 3.96$, $p < 0.05$. (Figure 2)

Figure 2: Children's perception of isolated melodies: the interaction between melody, types of comparison melodies and melody familiarity



For the same melody pairs of familiar melodies, participants performed better when hearing "Mary had a little lamb" than when hearing "Old McDonald had a farm". But for unfamiliar melodies, participants performed better when hearing rearranged "Old McDonald had a farm" than when hearing rearranged "Mary had a little lamb". For the different melody pairs with contour-preserved transformation of familiar melodies, participants performed better when hearing "Old McDonald had a farm" than when hearing "Mary had a little lamb". But for unfamiliar melodies, participants performed better when hearing rearranged "Mary had a little lamb" than when hearing rearranged "Old McDonald had a farm". For different melody pairs with contour-violated transformation, participants performed better when hearing "Mary had a little lamb" and its rearranged version, than when hearing "Old

McDonald had a farm” and its rearranged version. But there was no significant interaction between types of comparison melodies and melody familiarity, $F(2, 86) = 0.27$, $p = 0.76$.

Discussion

The participants found it easier to recognize the familiar melodies than unfamiliar melodies, and were better in recognizing same melody pairs than different melody pairs with contour-preserved melody pairs. They were also better in recognizing different melody pairs with contour-preserved transformation than with contour-violated transformation. This pattern was shown in both familiar and unfamiliar melodies as there was no interaction between familiarity of melodies and types of comparison melodies. This finding was different from the study by Trehub et al. (1985), who found that the children participants were better in recognizing the contour-violated transformation as different from the standard familiar melody than the contour-preserved transformation. This finding was also in contrast with that of Morrongiello, et. al. (1985), who had the same finding as Trehub et al. (1985) on unfamiliar melodies. For both the contour-preserved and contour-violated transformations of the standard melodies, only one note was varied. As demonstrated in the study by Morrongiello, et. al. (1985), the effect of contour on discriminability of melody was a differential one. With more notes varied to bring about the contour change, it will be easier to recognize the transformed melody as different from the standard one. In my study, it might be the case that the note varied was not sufficient to bring about the contour difference between contour-preserved and contour-violated transformations so that the expected difference in recognition of isolated melodies in contour-preserved and contour-violated transformations could not be seen. According to the conclusions made by Trehub, et al. (1985) and Morrongiello, et. al. (1985), children recognize both familiar and unfamiliar melodies using the cues from contour and frequency ratio. But the cue from contour was more important. In this study, the participants were not able to use the contour to help them in recognizing the isolated melodies as the contour change was not large enough. Then they use the frequency ratio to recognize the melodies. Both contour-preserved and contour-violated transformation had different frequency ratios from the standard melody. This might be a reason why the expected difference in performance on contour-preserved and contour-violated transformation was not shown.

The participants aged three had significantly different performance from the other age groups. The participants aged four also performed significantly differently from the participants aged ten. From this finding, it can be inferred that children's perception of isolated melodies undergo a developmental change from age three to age ten. A large leap in the ability occurs between age three and age four. Then from age four to age ten, the progress was relatively slower so that a significant change in perception of isolated melodies occurs over a larger age range.

Experiment 2: Recognition of Interleaved Melodies

The aim of experiment 2 was to determine the effect of contour on children's perception of familiar and unfamiliar interleaved melodies. The children's perception of interleaved melodies with different mean frequency separation between the comparison melody and the distracter tone sequence will also be compared. It was expected that the participants will be better in discriminating the interleaved melodies with greater mean frequency separation between the comparison melody and the distracter tone sequence, being the same as the findings in the studies by Dowling (1973) and Bey and McAdams (2003). Perception of interleaved melodies by participants of different ages will be contrasted to look for any difference.

Method

Participants

A different group of children were recruited from the same schools as experiment 1. Ninety-one children participated in this experiment. Forty-five children were excluded from the sample because they either did not understand the task of hearing screening (n = 4), failed in the hearing screening (n = 15), or failed in the training phase of the experiment (n = 26). One child was absent on the day of performing the tasks of the experiment. The final sample of 45 children consisted of 16 males and 29 females, with the age range of 3;04 – 6;10 and 10;00 – 10;11, and a mean age 6.20.

Stimuli

For the two training phases, the standard melody used was the first musical phrase of "Mary had a little lamb", consisting of seven notes. The comparison melody used in the different pairs was the contour-preserved transformation of "Mary had a little lamb", same as that in experiment 1. All the comparison melodies in the same and different pairs were interleaved with distracter tone sequences. The mean frequency separation between the comparison melodies and the distracter tone sequences was 10ST. In the first training phase, the amplitude of the distracter tone sequences was in half the amplitude of the comparison melodies. In the second training phase, the amplitude of the distracter tone sequences and the comparison melodies was the same.

For the testing phase, the familiar standard melody used was the first musical phrase of "London Bridge is falling down", consisting of seven notes. The unfamiliar standard melody used was the rearrangement of the notes of the familiar standard melody in a random order. Different distracter tone sequences were interleaved with the familiar and unfamiliar standard and comparison melodies. The participants were divided into two groups to be tested with two different types of conditions, so that different notes are varied in the melodies to bring about the transformation. The participants would not expect the same note to vary in each comparison melody. In type one conditions, the second and fifth notes of familiar standard melody was raised 4ST to have the contour preserved and contour violated transformations of the familiar standard melody respectively. The second and third notes of unfamiliar standard melody was lowered 4ST to have the contour preserved and contour violated transformations of the unfamiliar standard melody respectively. In type two conditions, the fifth and second notes of familiar standard melody was lowered 4ST to have the contour preserved and contour violated transformations of the familiar standard melody respectively. The third and second notes of unfamiliar standard melody was raised 4ST to have the contour preserved and contour violated transformations of the unfamiliar standard melody respectively. Each participant of the testing phase was tested with all three kinds of mean frequency separation between the comparison melodies and the distracter tone sequences: 0ST, 6ST and 12ST. The comparison melodies and the distracter tone sequences were in the same amplitude. Appendix 1 listed the frequencies of the component notes of the familiar and unfamiliar melodies and their transformations.

The distracter tone sequences used in the training and testing phases was first generated with 0ST mean frequency separation from the comparison melody, in a similar way as that in the study by Bey and McAdams (2003). Then the distracter tone sequence used in the training phases was transposed down 10 ST to interleave with the comparison melodies. Similarly, the distracter tone sequences used in the testing phase was transposed down 6 and 12 ST to interleave with the comparison melodies. Appendix 1 listed the frequencies of the component notes of the distracter tone sequences.

The tones of the melodies were complex tones. The standard melodies have the same duration as the melodies in experiment 1. For the interleaved comparison melodies, each tone in the comparison melody was 120ms in duration. The tones in the distracter tone sequences were 180ms in duration and played in the intertone intervals of the comparison melodies. Each interleaved comparison melody was also 2.07s in duration. Each tone of the melodies was presented at an average intensity level of 75dBA, measured with fast reading setting. .

Apparatus

The apparatus used was the same as that in Experiment 1.

Procedure

Before the experiment, the same hearing screening as experiment 1 was administered on the participants. The arrangement of the equipment and the seating in the experiment was also the same as that of experiment 1. During the experiment, the participant was asked to listen to two songs sung by some animals. The first song was sung by an animal as shown in a picture. The second song was sung by two animals hidden in a house shown in a picture. He/She had to hear the two songs to see if the first song was also sung by one of the two animals in the second song. If so it indicated that the animal who sang the first song was also one of the two animals who sang the second song and it was regarded as the same. If not it indicated that the animal who sang the first song and the two animals who sang the second song were different and it was regarded as different.

The format of running the trials, the response mode of the participants and the feedback were the same as that in experiment 1.

The experimental procedure consisted of two phases: training phase and testing phase. The training phase was further divided into two stages. In both training phases, a maximum of 20 trials were given. The same number of same and different melody pairs were presented. The order of presentation was randomized so that it was different for every participant. The participants should get five consecutive correct responses in both training phases to proceed to the second testing phase. If the participant was not able to get five consecutive correct responses within the 20 trials in the first or second training phase, he/she would be regarded as failing in the training and would not proceed to the testing phase.

In the testing phase, the same number of same and different melody pairs were presented. The order of presentation was also randomized. For the different melody pairs, there were equal number of pairs with contour-preserved transformation and contour-violated transformation. For all the melody pairs, the comparison melodies were interleaved with the distracter tone sequences in all the three types of mean frequency separation. Participants were tested with both the familiar and unfamiliar melodies under all the conditions. There was one trial for each condition using each of the two melodies. As a result, in the testing phase, there were 24 trials. The participants had to finish all the trials. The hearing screening and the experiment lasted about 20 minutes.

Results

The data consisted of the proportion of correct responses on same melody pairs and the two types of transformations of different melody pairs. For the age three group, there were only four participants. The number of participants were much less than that of the other age groups (n = 9 to 12). So the data of the age three group were excluded from the other four age groups for inferential statistical analysis. The data was presented in table 1.

Table 1

Average proportion of correct responses of age three participants (n = 4) in perception of interleaved melodies

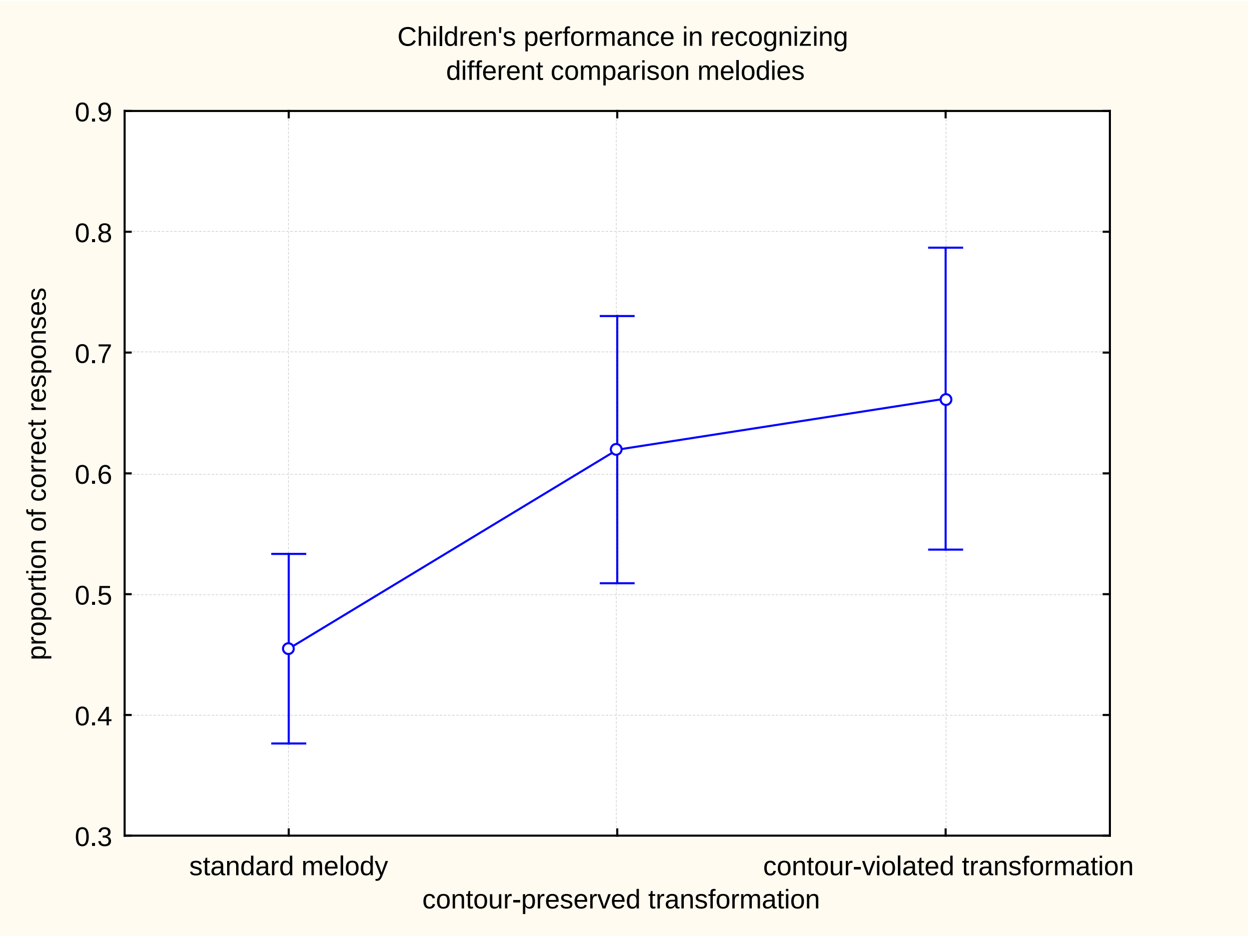
comparison melodies	Familiar melody			Unfamiliar melody		
	0 ST separation	6 ST separation	12 ST separation	0 ST separation	6 ST separation	12 ST separation
Standard melody	0.75	0.625	0.5	0.75	0.5	0.5
Contour-preserved transformation	1	0.75	0.5	0.5	0.25	0.5
Contour-violated transformation	0.25	0.75	0.25	0.25	0.75	0.5

When collapsing across mean frequency separation (0ST, 6ST and 12ST) and types of comparison melodies (standard melody, contour-preserved transformation, contour-violated transformation), participants of age 3 performed better with familiar melodies than unfamiliar melodies. When the factors of familiarity and types of comparison melodies were collapsed, participants had the highest proportion of correct responses with the mean frequency separation of 6ST, then 0ST. Participants had the lowest proportion of correct responses with the mean frequency separation of 12ST. When factors of melody familiarity and mean frequency separation were collapsed, participants performed the best with same melody pairs, then different melody pairs with contour-preserved transformation, then different melody pairs with contour-violated transformation.

For the age groups of four to ten, a mixed analysis of variance with age (age four, five, six and ten) as a between-subjects factor and melody familiarity (familiar and unfamiliar), types of comparison melodies (standard melody, contour-preserved transformation and contour-violated transformation) and mean frequency separation (0 ST, 6 ST and 12 ST) as within-subjects factors was performed on the proportion scores of correct responses. The main effect of melody familiarity was not significant, $F(1, 37) = 0.02$, $p = 0.900$. The factor of melody familiarity was also not involved in any significant interaction. So the data were collapsed across the two levels of melody familiarity. A mixed analysis of variance with age as a between-subjects factor and types of comparison melodies and mean frequency separation as within-subjects factors was performed on the collapsed data.

The main effect of types of comparison melodies was significant, $F(2, 74) = 13.34$, $p < 0.05$. Figure 3 showed that articipants had the highest mean proportion scores of correct responses for different melody pairs with contour-violated transformation, then different melody pairs with contour-preserved transformation, then same melody pairs. Post-hoc comparison using Tukey's HSD test showed significant difference in performance only between different melody pairs with contour-violated transformation and same melody pairs.

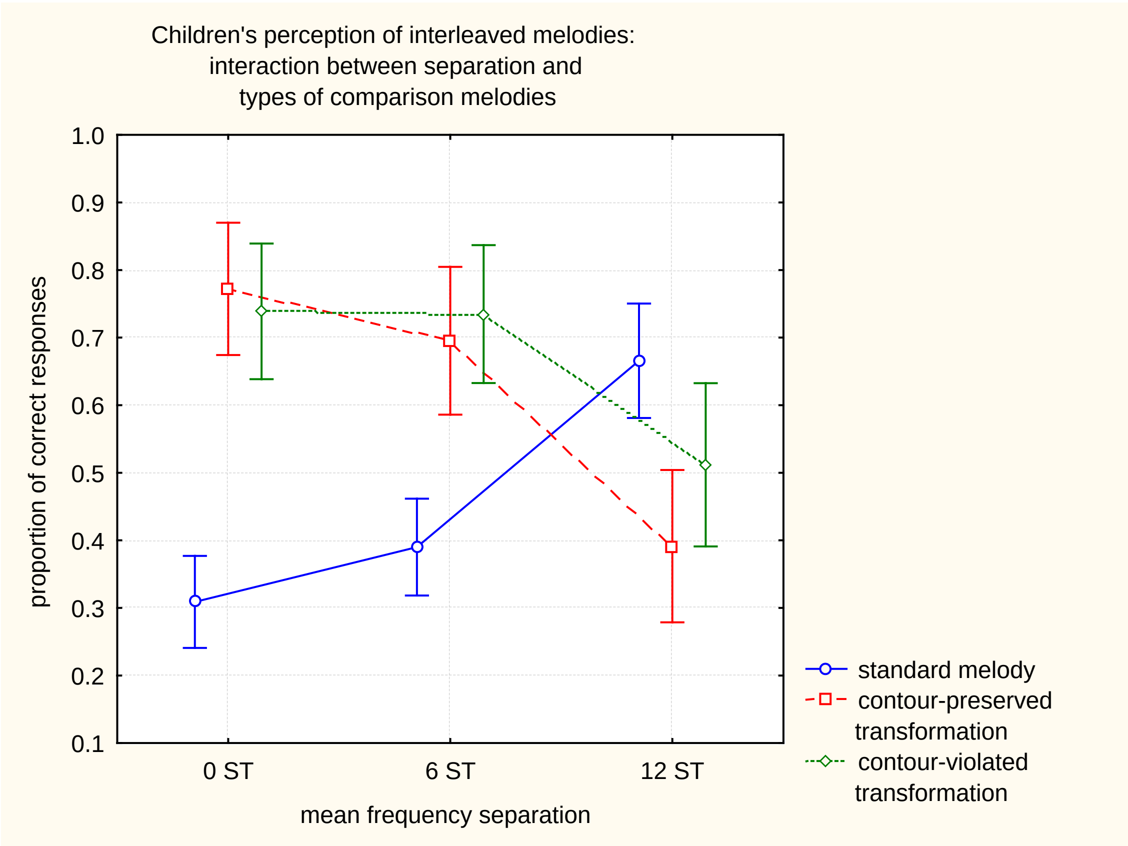
Figure 3: Children's performance in recognizing different comparison melodies



There was also a significant main effect of separation, $F(2, 74) = 3.48$, $p < 0.05$. Participants achieved about the same mean proportion scores of correct responses for the mean frequency separation of 0ST and 6ST. But they achieved lower mean proportion scores for the mean frequency separation of 12ST. But post-hoc comparison using Tukey's HSD test did not show significant difference between any two levels. The main effect of age was not significant, $F(3, 37) = 0.73$, $p = 0.54$.

In addition, there was a significant mean frequency separation $\times$ types of comparison melodies interaction, $F(4, 148) = 19.63$, $p < 0.05$. (Figure 3)

Figure 4: Children's perception of interleaved melodies: the interaction between mean frequency separation and types of comparison melodies interaction



For the same melody pairs, the mean proportion scores of correct responses increased with the mean frequency separation. But for the different melody pairs with contour-preserved transformation, the mean proportion scores decreased as the mean frequency separation increased. For the different melody pairs with contour-violated transformation, the mean proportion scores were about the same for the mean frequency separation of 0ST and 6ST, while for mean frequency separation of 12ST, the mean proportion score was lower. There was also a significant mean frequency separation × types of comparison melodies × age interaction, $F(12, 148) = 2.00$, $p < 0.05$.

Discussion

The performance of the age three group showed different pattern from the performance of the age four to age ten group. The age three group performed better with familiar melodies than unfamiliar melodies. But for the age four to age ten group, there was no significant difference in performance between familiar and unfamiliar melodies. Participants of age three had the highest mean proportion score of correct responses with the frequency separation of 6ST, then 0ST, then 12ST. For the age four to age ten group, the participants had about the same mean proportion score for mean frequency separation of 0ST and 6ST, then lower mean proportion score for mean frequency separation of 12ST, but no significant difference was shown between any two mean frequency separation. Also, for the age three group, participants' performance was the best with the same melody pairs, then different melody pairs with contour-preserved transformation, then different melody pairs with contour-violated transformation. But for the age four to age ten group, the reversed pattern of performance was shown. But there were only four participants in the age three group. Since the subject number was small, it was not known whether the performance pattern shown by the participants aged three in this study reflected the typical performance of three-year-old children in recognition of interleaved melodies.

The participants had significantly more correct responses in recognizing contour-violated transformations. This finding indicated that in perceiving interleaved melodies, contour was an important cue. It was because the comparison melody was interleaved with the distracter tone sequence. The participants' attention was distracted, as demonstrated in this study and that of Bey and McAdams (2003) by comparing performance in recognizing isolated and interleaved melodies. So the participants were able to attend only to the more obvious cue of the pattern of ups and downs of the notes. As a result, participants were better in discriminating different melody pairs with contour-violated transformation as comparison melodies. So contour was important in recognizing interleaved melodies.

The significant main effect of mean frequency separation showed better performance of the participants with both the mean frequency separation of 0ST and 6ST, than mean frequency separation of 12ST. This was contradicting with the performance of the adults participants in the study by Bey and McAdams (2003) that the recognition performance improved as the mean frequency separation increased. For the mean frequency separation of 0ST and 6ST, the participants showed difficulty in segregating the comparison melodies from the distracter tone sequences to compare with the standard melodies. So they simply guessed the answer. They guessed the melody pairs as different more frequently than same. As a result, the mean proportion scores of the mean frequency separation of 0ST and 6ST was only slightly above the chance level (M = 0.61). The graph showing the interaction between the factors of types of comparison melodies (similarity factor in the graph) and mean frequency separation (separation) also demonstrated that at mean frequency separation of 0ST and 6ST, there were more correct responses for different pairs than same melody pairs. For the 12ST mean frequency separation, the participants improved in discriminating same melody pairs. This finding reflected that the participants were better able to segregate the comparison melodies from the distracter tone sequences to compare it with the standard melody. But for the different melody pairs, the performance at 12ST mean frequency separation was lower than the other two mean frequency separations, although it reflected the true performance of the participants.

The main effect of age was not significant. It indicated that there was no developmental change in recognition of interleaved melodies from age four to age six and age ten, to bring about significant difference in performance among the age groups. This finding was surprising because before the study it was hypothesized that the participants of age ten group would have similar performance as the adults, as demonstrated in the study by Bey and McAdams (2003), that the recognition performance improved as the mean frequency separation increased. Conversely, being similar to the performance of the other age groups, the participants of the age ten group improved their performance in discriminating same melody pairs as the mean frequency separation increased. For the different melody pairs, the proportion scores of correct responses decreased as the mean frequency separation increased. So the participants as old as age ten still did not recognize interleaved melodies as well as adults at 12ST mean frequency separation.

General Discussion

If we compare the proportion scores of recognition of isolated and interleaved melodies, the proportion scores for isolated melodies were generally higher than that of interleaved melodies. So in general, participants performed better with recognition of isolated melodies than interleaved melodies. It was because for the interleaved melodies, the participants' attention was distracted. With the distracter tone sequences simultaneously playing with the comparison melodies, it was difficult for the participants to focus their attention on the comparison melodies. Also, it is more difficult for the participants to understand the task of recognition of interleaved melodies compared with the recognition of isolated melodies, as the participants attempted more trials to pass the training phases of interleaved melodies.

The participants' performance of recognition of isolated and interleaved melodies also showed differences in pattern of performance. In recognition of isolated melodies, participants performed better with familiar melodies than unfamiliar melodies. But in recognition of interleaved melodies, there was no significant difference in recognizing familiar or unfamiliar melodies. For isolated melodies, participants had the best performance with same melody pairs, then different melody pairs with contour-preserved transformation, then different melody pairs with contour-violated transformation. But for interleaved melodies, the reversed pattern was shown. Also, significant developmental change occurred in recognition of isolated melodies from age three to age ten. But no significant developmental change occurred in recognition of interleaved melodies from age four to age ten. These differences in performance pattern of recognition of isolated and interleaved melodies worth further investigation, as it may give us insights of how children recognize melodies and hence speech sound differently in quiet environment and environment with different frequencies of background noises.

Comparing the performance of recognition of interleaved melodies by children participants in this study and the performance of recognition of interleaved melodies by adult participants in the study by Bey and McAdams (2003), adult participants performed better. At 12 ST mean frequency separation, adult participants in the study by Bey and McAdams (2003) got mean proportion of correct responses of about 0.8. But in this study, at 12 ST mean frequency separation, the children participants got mean proportion of correct responses of about 0.53. The reason for this difference might be that the adults were better than the children in recognizing interleaved melodies, or the adults understood the task better than the children. Also, in the study by Bey and McAdams (2003), the comparison melody was either the standard or the contour-violated transformation. As discussed in previous paragraphs, contour was an important cue in recognizing interleaved melodies. So the adults performed better. The difference in performance of recognition of interleaved melodies for children and adults should be studied further.

References

Bey, C. & McAdams, S. (2003). Postrecognition of interleaved melodies as an indirect measure of auditory stream formation. *Journal of Experimental Psychology: Human Perception and Performance, 29(2),* 267-279

Chang, H. W. & Trehub, S. E. (1977). Auditory processing of rlational information by young infants. *Journal of Experimental Child Psychology, 24,* 324-331

Cohen, A. J., Thorpe, L. A. & Trehub, S. E. (1987). Infants' perception of musical relations in short transposed tone sequences. *Canadian Journal of Psychology, 41(1),* 33-47

Dowling, W. J. (1973). The perception of interleaved melodies. *Cognitive Psychology, 5,* 322-337

Dowling, W. J. (1978). Scale and contour: two components of a theory of memory for melodies. *Psychological Review, 85(4),* 341-354

Dowling, W. J. (1994). Melodic contour in hearing and remembering Melodies. In R. Aiello, & J. A. Sloboda (Eds.). *Musical Perceptions.* New York: Oxford University Press

Dowling, W. J. (1994). The development of music perception and cognition. In D. Deutsch (Ed.), *The Psychology of Music* (2nd Ed.). London: Academic Press

Morrongiello, B. A., Trehub, S. E., Thorpe, L. A., & Capodilupo, S. (1985). Children's perception of melodies: the role of contour, frequency, and rate of presentation. *Journal of Experimental Child Psychology, 40,* 279-292

Pick, A. D., Palmer, C. F., Hennessy, B. L., Unze, M. G., Jones, R. K. & Richardson, R. M. (1988). Children's perception of certain musical properties: scale and contour. *Journal of Experimental Child Psychology, 45,* 28-51

Trehub, S. E., Bull, D. & Thorpe, L. A. (1984). Infants' perception of melodies: the role of melodic contour. *Child Development, 55,* 821-830

Trehub, S. E., Morrongiello, B. A., & Thorpe, L. A. (1985). Children's perception of familiar melodies: the role of intervals, contour, and key. *Psychomusicology, 5,* 39-48

Appendix 1

Frequencies of the component notes of the familiar and unfamiliar melodies, their transformations in the isolated and interleaved melodies, and the distracter tone sequences

Isolated melodies

O McDonald Had a Farm

1. Original melody:	F	F	F	C	D	D	C
	349Hz	349Hz	349Hz	262Hz	294Hz	294Hz	262Hz

Contour-preserved transformation:

F	F	F	(G#)	D	D	C
349Hz	349Hz	349Hz	207.5Hz	294Hz	294Hz	262Hz

Contour-violated transformation:

F	F	F	E	D	D	C
349Hz	349Hz	349Hz	330Hz	294Hz	294Hz	262Hz

2. Unfamiliar version (order of the notes decided by drawing lots):

D	C	F	D	F	C	F
294Hz	262Hz	349Hz	294Hz	349Hz	262Hz	349Hz

Contour-preserved transformation:

D	(G#)	F	D	F	C	F
294Hz	207.5Hz	349Hz	294Hz	349Hz	262Hz	349Hz

Contour-violated transformation:

D	E	F	D	F	C	F
294Hz	330Hz	349Hz	294Hz	349Hz	262Hz	349Hz

Mary Had a Little Lamb

1. Original melody:	E	D	C	D	E	E	E
	330Hz	294Hz	262Hz	294Hz	330Hz	330Hz	330Hz

Contour-preserved transformation:

E	D	(G#)	D	E	E	E
330Hz	294Hz	207Hz	294Hz	330Hz	330Hz	330Hz

Contour-violated transformation:

E D E D E E E
330Hz 294Hz 330Hz 294Hz 330Hz 330Hz 330Hz

2. Unfamiliar version (order of the notes decided by drawing lots):
D C E D E E E
294Hz 262Hz 330Hz 294Hz 330Hz 330Hz 330Hz

Contour-preserved transformation:
D (G#) E D E E E
294Hz 207.5Hz 330Hz 294Hz 330Hz 330Hz 330Hz

Contour-violated transformation:
D E E D E E E
294Hz 330Hz 330Hz 294Hz 330Hz 330Hz 330Hz

Interleaved melodies
London Bridge is Falling Down
1. Original melody: G A G F E F G
392Hz 440Hz 392Hz 349Hz 330Hz 349Hz 392Hz

a) change the 2nd note
Contour-preserved transformation:
G [C#] G F E F G
392Hz 554Hz 392Hz 349Hz 330Hz 349Hz 392Hz

Contour-violated transformation:
G F G F E F G
392Hz 349Hz 392Hz 349Hz 330Hz 349Hz 392Hz

b) change the 5th note
Contour-preserved transformation:
G A G F C F G
392Hz 440Hz 392Hz 349Hz 262Hz 349Hz 392Hz

Contour-violated transformation:
G A G F G# F G
392Hz 440Hz 392Hz 349Hz 415Hz 349Hz 392Hz

2. Unfamiliar version (order of the notes decided by drawing lots):

F	E	A	G	F	G	G
349Hz	330Hz	440Hz	392Hz	349Hz	392Hz	392Hz

a) change the 2nd note

Contour-preserved transformation:

F	C	A	G	F	G	G
349Hz	262Hz	440Hz	392Hz	349Hz	392Hz	392Hz

Contour-violated transformation:

F	G#	A	G	F	G	G
349Hz	415Hz	440Hz	392Hz	349Hz	392Hz	392Hz

b) change the 3rd note

Contour-preserved transformation:

F	E	[C#]	G	F	G	G
349Hz	330Hz	554Hz	392Hz	349Hz	392Hz	392Hz

Contour-violated transformation:

F	E	F	G	F	G	G
349Hz	330Hz	349Hz	392Hz	349Hz	392Hz	392Hz

Distracter tone sequences

1. London Bridge is falling down

a) 0 ST separation:	F#	B	D#	G#	D	A#	F#
	370Hz	494Hz	311Hz	415Hz	294Hz	466Hz	370Hz
b) 6 ST separation:	C	F	A	D	G#	E	C
	262Hz	349Hz	220Hz	294Hz	207Hz	330Hz	262Hz
c) 12 ST separation:	F#	B	D#	G#	D	A#	F#

185Hz 247Hz 155Hz 207Hz 147Hz 233Hz 185Hz

2. Scrambled London Bridge is falling down

a) 0 ST separation: F# D B D# G# F# A#

370Hz 294Hz 494Hz 311Hz 415Hz 370Hz 466Hz

b) 6 ST separation: C G# F A D C E

262Hz 207Hz 349Hz 220Hz 294Hz 262Hz 330Hz

c) 12 ST separation: F# D B D# G# F# A#

185Hz 147Hz 247Hz 155Hz 207Hz 185Hz 233Hz